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PROPERTIES OF SPRAY-DRIED ENCAPSULATED MILKFAT

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ABSTRACT

Encapsulated milkfat powders were prepared from emulsions containing 40-60% milkfat (either butteroil or cream) and carbohydrate matrices (sucrose, modified starch or all purpose flour). Optical microscopy showed powder particles that were spherical, with diameters ranging from 20-60 μm ; they appeared to contain smaller vesicles. Melting patterns evaluated with a differential scanning calorimeter (DSC) showed well-defined melting ranges that were related to encapsulant used. Moisture sorption isotherms of powders showed characteristic breaks caused by sugar crystallization followed by slight moisture desorption. The cost of encapsulating powders is estimated to be about \$0.206/kg plus the cost of butteroil and other ingredients. Powders with 50% butteroil encapsulated in all-purpose flour and sucrose were successfully substituted in biscuit, cookie and muffin formulations.

INTRODUCTION

REDUCED FAT CONSUMPTION due to changing dietary habits in the late 1980's resulted in a world-wide surplus of butter and storage problems (USDA, 1991). Though salted butter can be readily stored frozen for up to three years, freezer space is limited and costly (\$0.26/cwt/month). A storage life of 12 to 24 months at ambient temperatures can be achieved if the milkfat is converted to a powder (Claypool, 1984). Spray drying milkfat with functional encapsulants such as starch, proteins and sugars enhances stability of the powder. Stability is attained through the formation of microregions that protect the milkfat from oxidative deterioration during storage. We have demonstrated that anhydrous butteroil or cream may be successfully encapsulated in carbohydrate matrices (Onwulata et al., 1994a). Milkfat is considered to be a quality-enhancing ingredient in foods, with the melting characteristics being very significant. Proper and timely melting of milkfat is necessary in developing flavor and enhancing texture. Encapsulant materials protect flavor/oil compounds from oxidation by retarding diffusion of oxygen to the oil in the interior of the capsule. The choice of encapsulant is critical as the material will influence: (1) emulsion stability before drying; (2) flowability, mechanical stability, shelf life after drying; and (3) cost.

For the production of butter powders, the encapsulant matrix may consist of milk proteins, sugars and gums. We investigated the physical characteristics, thermal and moisture sorption properties of the spray-dried microcapsules. Baking trials were conducted with butteroil encapsulated in sucrose and flour in cookies, biscuits and muffins.

Method of manufacture

Anhydrous butteroil was purchased from a commercial distributor (Land o' Lakes, Minneapolis, MN). Encapsulants selected were sucrose, modified starch (M-starch)

(Capsul™, National Starch and Chemical Co., Bridgewater, NJ) and all-purpose flour (N-starch). An emulsifying agent (mono- and di-glycerides) was also used. The protein source was nonfat dry milk. Encapsulated powders were formulated to have 40, 50 or 60 % milkfat, 5 % emulsifier and 5 % nonfat dry milk. Moisture content of the encapsulated powders ranged from 1–4 %. Sample preparation was as shown in Fig. 1; however, figures were not available for reproduction in this report.

STRUCTURAL PROPERTIES

Microstructure

Optical images of powders containing 40 % fat, made from anhydrous butteroil or cream, with M-starch, sucrose, or N-starch as the encapsulating agent, reveal differences in structural features of the constituent particles related to the type of carbohydrate matrix formed by spray drying, but not to the source of milkfat. M-starch particles, containing either butteroil or cream were roughly spherical in shape. The cavities ranged in diameter from around 5 to 20 μm . The powder particles with sucrose as the encapsulant were smooth spheres. Powder particles containing N-starch as the encapsulant were large, roughly spherical, and contained an admixture of coarse granular material. In each case, particles with each type of encapsulant, containing 40 % milkfat as butteroil or cream, were comparable in size and structure, indicating that stable powders could be made from both sources of milkfat.

Table 1—Melting characteristics of milkfat encapsulated at the 40 % in carbohydrate matrices

Product	Surface Fat		Encapsulant		Phase Transitions			
	Peak	ΔH	Peak	ΔH	Peak	ΔH	Peak	ΔH
N-STARCH40	*	*	36.0	10.6	134.4	27.6		
SD			0.0	2.1	2.6	0.4		
M-STARCH40	15.2	15.3	34.1	2.5	112.8	58.4		
SD	0.2	0.2	0.1	0.8	0.2	4.1		
SUCROSE40	17.6	14.5	38.0	4.9	183.8	42.5	239.1	23.9
SD	0.6	0.0	0.0	0.1	0.2	0.0	0.1	1.7

* Insignificant melting peaks. -- No thermal products after carbohydrate peak N-starch = All-purpose flour and butter oil. M-starch = Modified starch and butter oil 60% milkfat SD = Standard Deviation. $\Delta H = \text{J/g}$. PEAK = C

Thermal properties

A Perkin-Elmer differential scanning calorimeter, Model DSC-7, equipped with an Intracooler II refrigeration unit was used to measure thermal characteristics (Perkin Elmer Corp., Norwalk, CT). To identify shifts and complex patterns in the thermograms of the encapsulated powders, it was first necessary to identify the melting peaks of the various components used in product preparation. Melting peaks for M-starch were around 99°C, N-starch at 118°C and sucrose at 190°C.

Typical DSC thermograms of the spray-dried powders with 40% anhydrous butteroil encapsulated in three different carbohydrates were obtained; the heat of melting and peak temperatures are listed in Table 1. As shown by the thermal profiles, two major melting zones are present for each product containing 40% encapsulated fat, indicating the melting of the surface or unencapsulated fat and then of the wall material. Capsules with sucrose as the encapsulating agent had three melting zones and a disassociation peak at 239°C. The thermal patterns are those of true capsules with defined event times for the melting of the various components comprising the powder.

The capsule must rupture at the appropriate temperature if encapsulated milkfat is to be used as a shortening in such products as dry bakery mixes. This permits the shortening to be delivered at the appropriate time; our DSC results suggest that it might be possible to tailor capsule rupture temperature to the baking process by careful choice of encapsulant.

Moisture sorption isotherms

Moisture sorption isotherms were obtained at 25°C by equilibrating 10-g powder samples with known water vapor pressures provided by saturated salt solutions (Rockland and Nishi, 1980). Sorption isotherms of powders encapsulated in sucrose, N-starch and M-starch, with 40 or 60% butteroil were presented in Fig. 3 (not available for reproduction in this report). Sucrose/butteroil powders showed familiar sorption patterns across the range of water activities examined. A break in the sorption isotherm between 40-50% relative humidity was reported for spray-dried milk powders, attributed to the crystallization of α -lactose monohydrate (Onwulata and Holsinger, 1994b). Oxidative stability may be expected for the sucrose/butter oil powders between 0.1 and 0.2 a_w and for M-starch and N-starch powders between 0.2 and 0.4 a_w , based on the moisture monolayers.

Baking studies

Milkfat (50% fat from butteroil) encapsulated in all-purpose flour or sucrose was substituted weight-for-weight for vegetable shortening and flour or sugar in standard biscuit, cookie and muffin formulations.

Texture profile analysis (TPA). The TPA analyses of biscuits, cookies or muffins are presented in Table 2. Significant differences between the control and the experimental products were found for cohesiveness, chewiness and the degree of elasticity. Hardness did not vary significantly, but gumminess and chewiness, which are dependent on product hardness, did vary. The result of substitution of the spray dried powder encapsulated in all purpose flour for conventional shortening yielded biscuits and

Table 2—Texture profile analysis of biscuits, cookies or muffins containing butteroil encapsulated in all purpose flour (FLBO50) or sucrose (SUBO50)

Product	Hardness (N)	Cohesiveness	Elasticity (N-mm)	Chewiness
Biscuits				
Control	3.34 b	0.39 b	0.40 c	7.67 b
FLBO50	3.09 a	0.36 d	0.33 d	5.55 c
Cookies				
Control	194 c	0.24 e	0.40 e	57.1 d
SUBO50	192 c	0.33 c	0.49 c	96.2 c
FLBO50	242 c	0.30 d	0.45 d	96.0 c
Muffins				
Control	10.6 c	0.29 c	0.54 c	30.0 c
SUBO50	10.3 c	0.27 d	0.42 e	22.2 d
FLBO50	10.1 c	0.30 c	0.49 d	26.7 e

HARDNESS: Height of first peak; COHESIVENESS: ratio of area under second peak to area of first peak (A2/A1); ELASTICITY: degree of elasticity; CHEWINESS: product of HARDNESS × COHESIVENESS × SPRINGINESS. Values in the same column for each product followed by different letters are significantly different by Analysis of Variance at P<0.05.

muffins of approximately equal textural quality, while the substitution of the spray-dried powder encapsulated in sucrose resulted in muffins and cookies of poorer texture, since more cohesive and chewy products are desired.

Volume. The volume measured for the three types of baked goods, by rapeseed displacement, is shown in Table 3. Biscuits made with the FLBO50 substituted formulation had a 5% increase in volume; a 3.9% decrease in volume was observed with cookies; but a 3.5% increase in cookie volume was seen with the sucrose (SUBO50) substituted formulation. Muffins containing FLBO50 increased 4.9% in volume while muffins with SUBO50 increased 5%.

Cost analysis

On the basis of a cost analysis, we have concluded that a desirable dry product containing milkfat may be produced at a cost of \$0.206/kg plus the cost of the dairy ingredients. The comparative cost of the materials is presented in Table 4.

Table 3—Effect of substitution of butteroil encapsulated in all purpose flour (FLBO50) OR SUCROSE (subo50) as shortening on volume displaced of biscuits, cookies, and muffins

Product	Volume displaced (cm ³)/std. dev.		
	Control	FLBO50-Substituted	SUBO50-Substituted
Biscuits	52.8/2.9	50.2/1.9	----
Cookies	67.2/2.6	64.6/3.3	69.6/2.1
Muffins	129.8/4.8	136.1/6.2	136.3/4.3

Table 4—Comparative cost of milkfat encapsulation

Ingredient	Material Cost/kg*	Encapsulated Product (kg)
All-Purpose Flour	\$1.191	\$1.339
Modified Corn Starch	\$1.091	\$2.287
Sucrose	\$1.329	\$1.476
Process		\$0.206

*. All raw materials including Emulsifier, NFDM, and Water.

Benefits

Spray-dried encapsulated milkfat powder shows great potential for use as a food ingredient in such products as dry bakery mixes. Well-defined melting ranges are identifiable in DSC profiles; melting temperatures for capsule rupture and release of the fat load are associated with the type of encapsulating agent chosen. Moisture uptake and sorption isotherms are also dependent on encapsulant and demonstrate the need for special packaging to prevent moisture imbibition during storage. Baking trials demonstrated the successful substitution of 50% milkfat encapsulated in all-purpose flour in cookie, and biscuit formulations. The convenience of storage and the ease with which the powder may be blended with other dry ingredients in a food processing operation are obvious benefits. Powders may be substituted for shortening in baked goods with considerable success. The encapsulation technology described offers new market opportunities for milkfat utilization to the dairy industry.

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Mention of brand or firm names does not constitute an endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

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